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# Improved Streamflow and Water Quality Monitoring Using a Microprocessor-Based System

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## ABSTRACT

*Describes microprocessor-based data acquisition system for monitoring streamflow and collecting water samples at remote sites. This system was more efficient and provided more precise data during high-intensity, short-duration rainstorms than the system used previously.*


KEYWORDS: watershed management, hydrological monitoring, data acquisition, stream sedimentation, erosion, environmental monitoring, electronic monitors

## INTRODUCTION

Accurate data quantifying effects of road construction, timber harvesting, and other forest management activities on water quality are often essential for evaluation of land management activities. Collecting such information has been difficult and costly for the Forest Service due to the remoteness of many sites and limitations of available sampling equipment. Advances in electronic technology now make possible microprocessor-based systems that reduce costs and enhance the information collected. The purpose of this report is to inform hydrologists and others about the capabilities of modern electronic monitoring devices.

## EARLY METHODS AND EQUIPMENT

Personnel with the Nez Perce National Forest and the Intermountain Research Station have been studying effects of road construction and timber harvesting on soil and water resources in the Horse Creek drainage, which is a part of the Meadow Creek barometer watershed, located near Elk City, ID. Project objectives call for measuring sediment production resulting from road construction.

As one approach, gaging stations with 1-ft H-flumes and automatic water sampling equipment were located on streams immediately above (station A) and below (station B) road crossings. The streamflow at station A was essentially free from effects of road construction and thus provided the control. Streamflow at station B was influenced by the road construction primarily through the additional flow coming in from the ditch on the cut-bank side of the road during rainstorms and snowmelt. A primary goal was the collection of high-resolution streamflow data and water samples during high-intensity, short-duration storms. Although the equipment is reliable, collecting such data during high-intensity, short-duration storms has proven difficult due to the limited bottle capacity and the types of triggering modes afforded by the automatic samplers. Moreover, precise synchronization of station A and station B flow records and water samples using standard equipment was not possible without equipment modifications.

Figure 1 is the stage record of a lower road crossing station (station B) for May 23, 1981. The spike near the center of the graph resulted from a thunderstorm that started just before 3 p.m. and dropped about 0.5 inch of

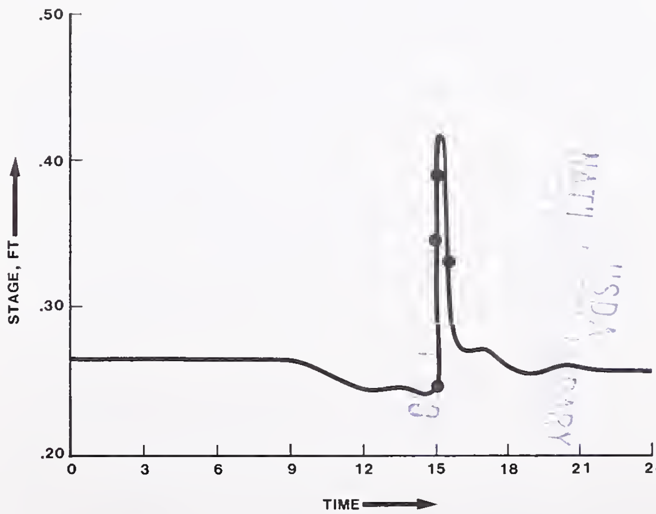


Figure 1—Stage record, May 23, 1981, road crossing #16, station B. (Dots indicate water sample collection points.)



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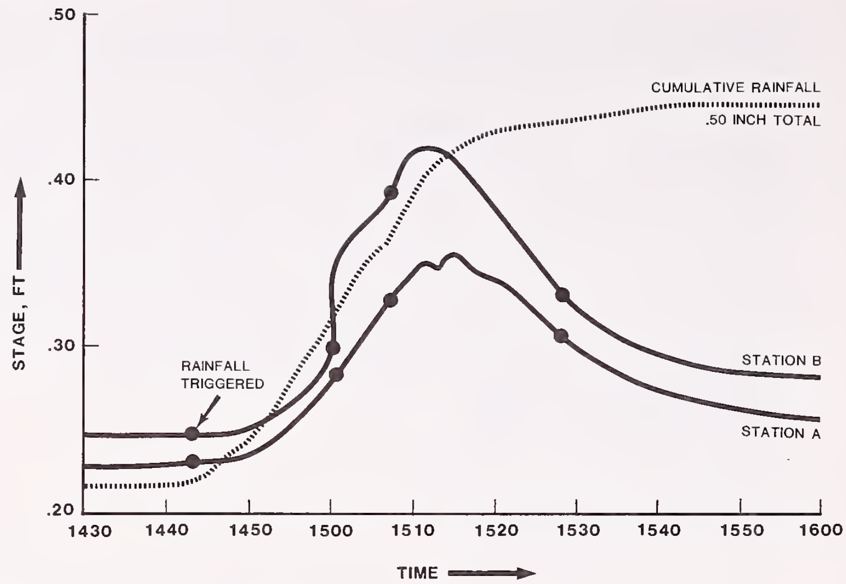


Figure 2—Cumulative rainfall and stage records, May 23, 1981, 4:30 to 6 p.m., road crossing #16, stations A and B. (Dots indicate water sample collection points.)

rainfall over 40 minutes. Providing much higher resolution of the same storm, figure 2 is a "window" from 2:30 p.m. to 6 p.m. and contains stage records from station A and station B, as well as cumulative rainfall.

Consider now the battery-powered sampler's capabilities—28 bottles and either fixed-time interval or flow-proportional sampling. If the service interval is once per week and operation is in time mode, four samples per day are required to maximize sampler efficiency. Thus, the probability of taking a sample during a 1/2-hour thunderstorm is only 0.08. Referring again to figure 1, and assuming samples were taken every 6 hours, starting at midnight, then indeed, no meaningful samples would have been collected. Moreover, service intervals of once per week to remote sites are costly and time consuming, and intervals of once per month more reasonable and typical.

Flow-proportional sampling, in which a sample is collected after a specified quantity of water has passed, is not much better, as most of the data again will be of base flow conditions. Only by chance would a sample be taken during an event such as that shown in figure 1; and even then its timing would depend on when the last sample was taken, not on the characteristics of the event itself. Clearly, techniques synchronizing storm events to the collection of samples are desirable in these situations.

Initially, a multipoint probe system was designed to trigger the sampler as the water level rose or fell between the points. Although sampler efficiency increased, this system was impractical as it was necessary to completely rewire the probe if altered sample points were required. Additionally, the streamflow strip chart recorder required modification to include an extra pen to mark the sample event.

## MICROPROCESSOR SYSTEM

Microprocessor system components operating over wide temperature ranges and requiring minuscule amounts of power became available in the late 1970's. Because microprocessor systems would substantially enhance the water sample collection process, a design effort was undertaken to meet the following objectives:

1. Sample collection activated by:
   a. Rising or falling stage
   b. Time interval (baseline information, typically once per week)
   c. Rainfall intensity.
2. Measure climatic parameters, as well as streamflow data.
3. Store pertinent data on cassette tape (6 month minimum capacity).
4. Trigger samplers above and below road simultaneously, based on data from lower station.
5. Operate for extended periods on battery-supplied power.
6. Operate under extreme environmental conditions.

Because of the lack of availability of system and circuit board level components suitable for field use, a completely new design was required. Design and fabrication of a prototype system was completed in February 1981. After 5 weeks of testing and calibration, the unit was installed at a road crossing gauging station in the Horse Creek drainage. A second system was installed in June of 1982, and both remained in operation until October 1983. The system (see block diagram, fig. 3) consists of a microprocessor, sensor and sampler interfaces, climatic and streamflow sensors, digital cassette tape, and control panel. In addition, a solar charging circuit was added to increase system reliability and to eliminate the need to change batteries.

An algorithm of the four methods leading to the triggering of the automatic samplers is given in figure 4. Samples are taken every 7 days at 12 p.m., providing baseline data. As with other key variables in the microprocessor system, this interval can be altered to suit the user's needs. The majority of samples collected are initiated by changes in stage as

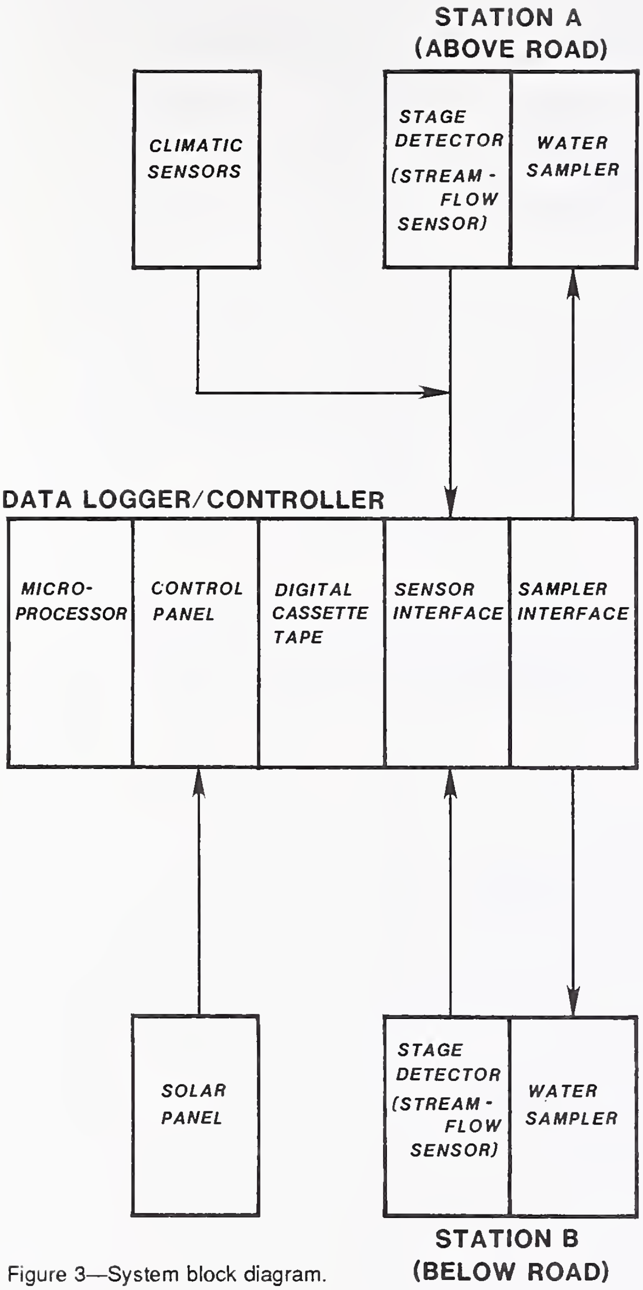


Figure 3—System block diagram.

measured by a pressure sensor. Water level fluctuations significant enough to cross threshold levels trigger the automatic sampler, at which time new threshold levels are calculated and set. The magnitude of the increment setting the new threshold level can be altered via the front panel keyboard. Falling stage increment is calculated to be twice the keyboard entered value; that is, the stage must fall two increments before the triggering threshold is crossed. This technique further extends service intervals without sacrificing the more important rising stage information.

A different triggering method, based on rainfall rate, was implemented to take a sample at the onset of a thunderstorm. If the rainfall, as measured by a tipping bucket rain gauge, exceeds a preset value over a 4-minute interval, then a sample is taken. Because a sample collected by this technique is desired only at the start of a storm, subsequent rainfall triggers are inhibited for 24 hours. Lastly, sample initiation can be accomplished through keyboard controls, providing servicing personnel a means to check system performance. Referring to figures 1 and 2, the dots mark the stage levels where samples were taken. The first sample was rain-induced, the next two were taken on the rising stage, and the final one was collected on the falling stage.

Sampling based on the algorithm described above has worked well for the Horse Creek study, but is only one of many schemes possible. Other techniques could include rate of change of streamflow, or triggering based on other parameters, such as cumulative solar radiation for sampling during snowmelt periods. Indeed, microprocessor systems are extremely versatile because their function can be altered significantly without extensive hardware modification. It should be noted that this added flexibility in itself will not optimize the collection of water samples; the hydrologist must select suitable sample initiation levels.

All information collected is stored digitally, which offers a much higher degree of resolution than available with analog methods. Using conventional strip charts for long-term recording instruments mandates slow chart speeds and a subsequent loss of resolution. Electronic memories or digital cassette tapes are far superior to strip charts for storage of data. It would be very difficult to obtain resolution of a strip chart to the degree shown in figure 2.

Another important consequence of electronic data recording is ease of transferring field information to a larger computer for long-term storage and analysis. Large backlogs of strip charts to be read often occur because the transcribing process is both tedious and time consuming. Several months of streamflow, rainfall, air temperature, and other data can typically be transferred from digital cassette tape in a matter of minutes. Errors in transcribing the data are virtually eliminated using digital methods, as the error rate is less than one in a million. Hydrographs can be constructed via a computer and plotter from the digital data, if desired.

But the system was not without problems. Foremost was accuracy and reliability of the pressure sensors used to measure water stage. Original sensors exhibited a high degree of hysteresis, resulting in jumps in the data instead of a smooth progression. Further, freezing water would burst the sensing diaphragm, destroying the sensor. New, more expensive pressure sensors eliminated the "jumpy" data, but no reasonable solution to the freezing problem has been found.

Another difficulty was the "unfriendliness" of the system. For maximum utility personnel must be comfortable with the operation of any piece of equipment. This system posed problems because some of the key variables are listed in octal (instead of decimal), and values are entered via a hexadecimal keyboard.

## COST

Cost estimates for automatic sampling equipment required to measure sediment production at a road crossing site are given in table 1. Cost of the microprocessor controller varies with the wages for approximately 60 hours of labor needed to assemble a single unit (wages of $20.00 to $80.00 per hour were used). Instruments measuring climatic parameters, such as rainfall, are more expensive

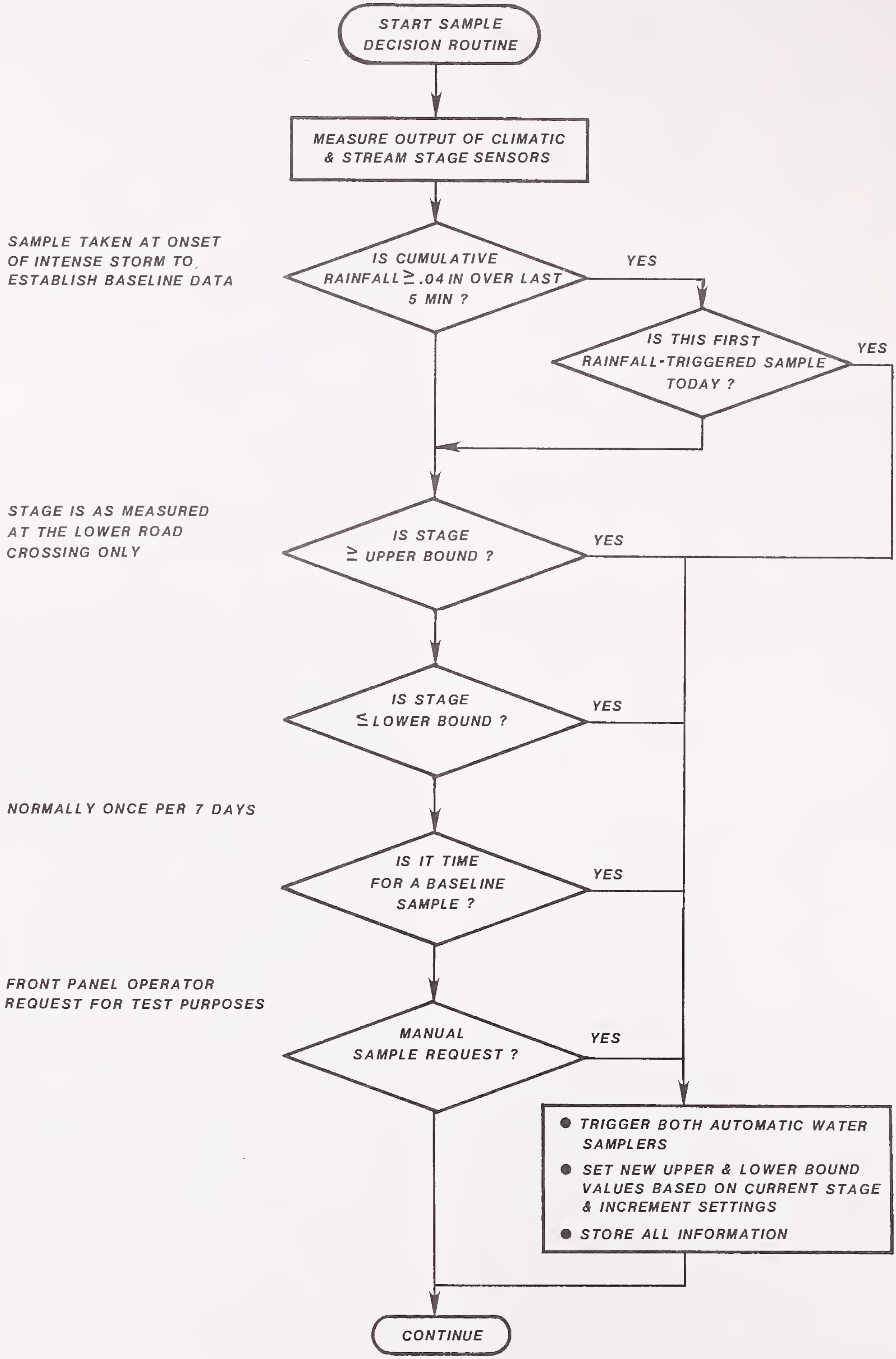


Figure 4—Water sample initiation algorithm.

**Table 1**—Purchase price comparison of hardwire and microprocessor systems

| Equipment descriptions | Hardwire systems | Microprocessor system |
|---|---|---|
| | *Dollars* | *Dollars* |
| Sampler (2) | 3,900 | 3,900 |
| Flowmeter (2) | 3,500 | 3,500 |
| Flow recorder (2) | 2,400 | |
| Fiberglass 1-ft H-flume with approach (2) | 800 | 800 |
| Microprocessor controller | | [1]4,200-7,800 |
| Climatic instrumentation | 1,700 | 500 |
| Total | 12,300 | 12,900-16,500 |

[1]Range variance due to assembly costs, see text.

when used in conjunction with the hardwired logic system, because each requires a self-contained data-logging device. Shelter costs, which can add substantially to the total, are not included in the table as they will vary considerably, depending on such factors as length of measuring period, vandalism protection, snow accumulations, and other factors.

Due to the dissimilarity of operation and output between the systems it is difficult to compare operating costs. Direct savings will be realized through extended service intervals and reduced data transfer costs associated with the microprocessor system. The real value of the microprocessor system lies in those applications requiring improved sample distributions, reduced error rates, and integrated data sets.

In the period since this system was designed, low-power, single-board microprocessor systems suitable for field use have become available. A streamlined version of the system described here could be assembled from commercially available circuit boards, substantially reducing the fabrication effort as well as the cost.

For further information regarding this system or suggestions on assembling an updated version, please contact:

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